**Introduction**

There have been few exciton measurements made for helium, all of which are for 4\text{He}. The measurements have been of svp (saturated vapor pressure) liquid at 1.2K using EUV reflectance measurements,\textsuperscript{1} clusters of sizes up to \(N=5000\) using fluorescence measurements,\textsuperscript{2,3} and 13.5 cm\(^3\)/mole solid hcp 4\text{He} using inelastic x-ray scattering.\textsuperscript{4} This experiment was done to take better resolution measurements of helium excitons, to look for dispersion in the hcp solid and density scaling in the liquid.

**Methods and Materials**

This inelastic x-ray scattering experiment was conducted at ChemMatCARS on the 15-ID beamline. The energy of the monochromator was set to 9.8865 keV, with a measured bandpass of 1.1 eV FWHM. The analyzer used was a spherically bent silicon crystal employing the (555) reflection.

Helium crystals form only under applied pressure, even at the lowest temperature. Our setup (previously described by Venkataraman and Simmons\textsuperscript{5}) involves a gas-handling system able to provide 210 MPa of pressure, and a cryostat able to go down to 10K. The helium samples were contained in a cylindrical beryllium sample cell (0.8 mm ID). Empty cell measurements at 25.0K were taken at the same orientation as the data measurements at the end of the run. A preliminary empty-cell measurement with a short count time is shown in Fig. 1, along with a data scan, showing the reproducibility of the beryllium excitations at energies lower than the helium exciton.

Three 4\text{He} samples were studied: an hcp crystal at 14.0K with a molar volume of 10.72 cm\(^3\)/mole and two liquid samples at 25.0 K with molar volumes of 11.22 cm\(^3\)/mole (liquid A) and 12.27 cm\(^3\)/mole (liquid B). The hcp crystal had a c lattice parameter of 4.782 Å, taken from the molar volume found from comparison of its measured melting point to previous melting curve studies.\textsuperscript{6,7} Three measurements were done for the crystal at different points in reciprocal space, near the (002) reflection along the c-axis.

**Results**

To extract the helium signal, the normalized empty-cell scans were directly subtracted from the normalized data scans without any scaling. Fig. 2 shows the data and empty-cell normalized scan, showing the full range of the background due to beryllium excitations. The data had 30 s/point, while the background had 40 s/pt.

FIG. 1. These are preliminary scans of empty-cell background and data, showing the full range of the background due to beryllium excitations. The data had 30 s/point, while the background had 40 s/pt.

FIG. 2. These are the data and empty-cell normalized scans for 12.27 cm\(^3\)/mole liquid. The data scan was taken with 240 s/pt, while the background scan was taken with 300 s/pt.

FIG. 3. This is the 30.0° measurement for the hcp crystal. A Gaussian plus a linear function has been fit to the data, giving the exciton energy as the position of the Gaussian.
scans for liquid B. The empty cell subtracted data are fitted to a Gaussian plus a linear function. An example of this is in Fig. 3, which is the 30.0° crystal data. The Gaussian position is the energy of the exciton. The summary of results are in Table 1, where $Q$ is the momentum transfer of the photons, and $Q^*$ is the reduced momentum transfer in terms of the c-axis. The uncertainty of $2\theta$ is ±1.5°, while for $Q$ it is ±0.13 Å⁻¹.

**Discussion**

The three crystal measurements can be represented as along the c-axis of the third periodic zone at -1.0Å, Γ, and 0.6Å. The corresponding measured excitons exhibit dispersion with a minimum at the zone center Γ. The data support a calculated value of 31.0 eV for an interband transition across the minimum bandgap which occurs at Γ. The liquid measurements show a shift to higher energy for the exciton as the density is increased.

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**References**


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<th>Sample</th>
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